RESEARCH BULLETIN 988 SEPTEMBER 1966

A Method for ESTIMATING SOIL MOISTURE UNDER CORN, MEADOW, AND WHEAT

L. T. PIERCE

Ohio Agricultural Research and Development Center
WOOSTER, OHIO

CONTENTS

* * * * *

ACKNOWLEDGMENTS

The author expresses appreciation to the following persons for their assistance with this project: L. L. Harrold, project supervisor, Soil and Water Conservation Research Station, USDA, Coshocton, Ohio, and professor of agricultural engineering, Ohio Agricultural Research and Development Center, for making manuscript lysimeter data available for this study; G. H. Snyder, student trainee in the U. S. Weather Bureau, Columbus, Ohio, 1959 and 1960, for assistance in development of the special slide rule; and Dr. J. B. Jones, Jr., professor of agronomy, Ohio Agricultural Research and Development Center, for helpful advice and for arrangement of material for publication as a Research Center bulletin.

AGDEX 561 9-66-2M

A Method for Estimating Soil Moisture Under Corn, Meadow, and Wheat

L. T. PIERCE[1]

SUMMARY

This bulletin presents a formula method of estimating water use by crops and determining the amount of moisture remaining in the soil at any particular moment. Mean daily air temperature and rainfall are the only measurements required.

Water use as evapotranspiration is estimated from the formula:

$$ET = PE \times L \times D \times C \times R$$

where ET is evapotranspiration, PE is potential evapotranspiration, and L, D, C, and R are corrections for day length, soil dryness, crop stage, and the occurrence of rainfall.

A water budget for corn, wheat, and meadow can be calculated with this formula. Budgeting begins by assuming the soil profile is at field capacity at the start of the growing season (approximately April 1). Rainfall (less estimated runoff) is budgeted into the soil moisture supply and ET is computed and deducted from the soil moisture supply. Thus, a continuous record of the soil moisture status can be obtained.

INTRODUCTION

An adequate and continuous supply of soil moisture is essential for optimum plant growth. However, the amount of available soil moisture is not easily determined, particularly on a continuous basis. Numerous direct measurement methods have been proposed (9) but most of these methods either require specialized equipment or are not practical when continuous measurements are desired.

Efforts have been made recently to develop a formula method for estimating soil moisture by utilizing weather data, particularly precipitation and air temperature. Precipitation provides a measure of the amount of water added to the soil profile and air temperature provides a measure of the evaporative force of the atmosphere. Soil moisture depleted at the surface of the soil profile by evaporation and by transpiration of plants is referred to as evapotranspiration (ET). It is possible to estimate ET from meteorological observations.

This bulletin describes a method for estimating ET which is a modification of Thornthwaite's method (12). Soil moisture is determined by balancing ET against measured precipitation. Soil moisture then may be expressed as the amount of water present or as a deficit below field capacity. The latter method of expression is used in this bulletin.

The method described in this bulletin includes the earlier work of the author (8) and further extension of the formula method to include corn and wheat. Modification and extension of the Thornthwaite method was accomplished by detailed comparisons with soil moisture and ET records obtained by weighing lysimeters at the USDA Soil and Water Conservation Research Station at Coshocton, Ohio (5).

A standard exposure is assumed and is defined as a slightly sloping, well-drained site where water does not accumulate after heavy precipitation. Deviations from this standard exposure can result in overestimation or underestimation of ET or soil moisture by as much as 20 percent. If ET is overestimated or underestimated, the crop moisture deficit (CMD) will indicate the soil to be drier or wetter than it actually is.

Highest values of ET are generally experienced on south-facing slopes and on level land, while lowest values are found on north-facing slopes. Sites having a steep slope will be drier, while those in low spots will be wetter than indicated by these computations. Users should take these factors into consideration and make such adjustments in the ET rate as appear necessary to obtain best results in individual situations.

The effect of soil type on ET is not known with sufficient certainty to suggest deviations from results obtained with these formulas. Soil type affects the rate of water use by growing crops, principally due to moisture holding capacity and rate of infiltration.

REVIEW OF LITERATURE

Formulas for estimating ET have been proposed by Penman (7), Thornthwaite (12), and Blaney-Criddle (3). Penman's (7) heat budget method estimates the amount of water evaporated from soil and leaf surfaces by computing the heat available for

[1]Formerly state climatologist, U. S. Weather Bureau, Columbus, Ohio, now research climatologist, Ohio Agricultural Research and Development Center

evaporation under prevailing weather conditions. Thornthwaite's (12) estimate of ET is based on an empirical relationship between air temperature and potential evapotranspiration (PE). The Blaney-Criddle (3) method of estimating ET is similar to Thornthwaite's method in some respects and is widely used in the western United States. However, this method has not been found to be equally applicable to other sections of the United States.

The Penman and Thornthwaite ET estimate methods can be applied on a daily or weekly basis. The Blaney-Criddle method is used mainly to estimate monthly or seasonal ET.

Numerous extensions and adaptations of these three methods have been devised. Van Bavel (13) used the Penman method to document agricultural drought. Tanner and Pelton (11) conducted extensive studies with the Penman method. Tanner (10) also applied the energy balance concept of Penman to studies of soil moisture under alfalfa-brome and corn.

Jensen and Haise (6), using Penman's basic concept of energy balance, developed a method for estimating ET from solar radiation. Decker (4) used an extension of Penman's method to describe the energy budget and extent of evapotranspiration in corn.

Arkley and Ulrich (1) used the Thornthwaite method for determining ET throughout the state of California under varying climatic conditions. Pierce (8) used an extension of the Thornthwaite method to estimate ET over meadow.

TABLE 1.—Moisture Constants for 34 Ohio Soils (Expressed in Terms of Inches H_2O)*.

Soil Type	Location	30-inch Profile			42-inch Profile		
		FC	PWP	Avail.	FC	PWP	Avail.
Avonburg S. L.	Warren Co.	10.71	5.73	4.98	15.01	8.69	6.32
Blanchester S. L.	Warren Co.	12.09	7.54	4.55	17.22	10.64	6.58
Blount S. L.	Allen Co.	9.94	6 08	3.86	13.53	8.66	4.87
Brookston SCL	Franklin Co.	11.62	6.75	4.87	15.22	9.26	5.96
Canfield S. L.	Wayne Co. (Wooster)	9.28	4.33	4.95	12.50	6.52	5.98
Celina S. L.†	Franklin Co.	9.57	3.96	5.61	12.94	5.46	7.48
Clermont S. L.	Clinton Co.	10.83	6.58	4.25	15.62	9.57	6.05
Colermie S. L.	Ross Co.	10.33	4.54	5.79	14.02	6.26	7.76
Coolville S. L.	Ross Co.	11.20	5.96	5.24	15.58	10.12	5.46
Crosby S. L.	Franklin Co.	11.67	6.43	5.24	14.84	8.13	6.71
Crosby S. L.	Clark Co.	10.90	4.74	6.16	14.79	6.07	8.72
Frenchtown S. L.	Ashtabula Co.	9.19	4.56	4.63	12.15	5.95	6.20
Fulton SCL	Wood Co.	11.14	7.24	3.90	15.58	10.60	4.98
Genesee S. L.	Ross Co.	10.56	4.21	6.35	14.95	5.96	8.99
Griggs S. L.	Ashtabula Co.	9.43	4.97	4.46	12.78	7.46	5.32
Haney Sandy Loam	Van Wert Co.	7.51	3.18	4.33	9.76	4.50	5.26
Haskins Loam	Wood Co.	7.80	3.79	4.01	11.16	4.77	6.39
Hoytville Silty Clay	Wood Co.	11.69	7.27	4.42	16.02	10.47	5.55
Hoytville Silty Clay	Wood Co.	10.90	4.28	6.62	14.79	6.11	8.68
Keene S. L.	Coshocton Co.	11.33	4.64	6.69	16.61	7.16	9.45
Latty Clay	Paulding Co.	11.48	8.61	2.87	15.78	12.26	3.52
Loudon S. L.	Brown Co.	10.95	6.61	4.34	16.73	10.86	5.87
Meigs S. L.	Meigs Co.	9.46	4.79	4.67	13.22	7.00	6.22
Miami S. L.	Franklin Co	9.77	5.04	4.73	13.32	6.75	6.57
Morley Clay	Allen Co.	9.86	7.10	2.76	13.56	10.49	3.09
Muskingum S. L.	Coshocton Co.	8.77	2.98	5.79	11.90	3.94	7.96
Napanee S. L.	Wood Co.	9.26	6.07	3.19	12.67	8.83	3.84
Pewamo Silty Clay Loam	Allen Co.	11.66	8.08	3.58	16.87	11.64	5.23
Rossmoyne S. L.	Clinton Co.	10.66	5.19	5.47	14.46	7.96	6.50
Rossmoyne S. L.	Brown Co.	10.00	5.33	4.67	14.82	7.62	7.20
Russell S. L.	Preble Co.	10.46	4.99	5.47	14.24	7.21	7.03
Sheffield S. L.	Ashtabula Co.	9.82	6.16	3.66	13.03	8.91	4.12
Sloan SCL	Ross Co.	10.91	4.99	5.92	15.29	6.99	8.30
Toledo Silty Clay	Wood Co.	11.94	8.02	3.92	16.90	11.55	5.35
Trumbull Silty Clay	Trumbull Co.	10.02	6.72	3.30	15.30	9.65	5.65

*Moisture in inches was computed by the author from mechanical analysis sheets of the Ohio State Division of Lands and Soil and The Ohio State University Dept. of Agronomy.

†Determinations initially made by The Ohio State University Dept. of Agronomy and subsequently adjusted by gravimetric sampling.

SOIL MOISTURE CHARACTERISTICS

Water enters the soil primarily as precipitation. Precipitation either runs from the surface on which it falls, evaporates into the atmosphere, or is absorbed into the soil. When the pore spaces between soil particles are filled with water, the soil is said to be saturated. This is only a temporary condition since much of the water entering the soil profile will drain or percolate to greater depths.

The field capacity (FC) of a soil is defined as the greatest amount of water which can be held against the force of gravity. So the FC is that quantity which remains after the surplus has drained away. All water at or below the FC is held in contact with soil particles by surface tension as films or membranes of water. This water is defined as "capillary water" and can be extracted from the soil profile only by evaporation or absorption by plant roots. When evaporation is occurring at the surface, there is a very slow upward movement of moisture to the surface from depths as great as 2 feet or more.

As the capillary films of water become thinner, the remaining water is titled "hygroscopic" water. This water is held so tightly that it cannot be extracted by plant roots. The soil percent at which this condition exists is called the permanent wilting point (PWP). This is generally considered the lower limit of available soil moisture. Therefore, available soil moisture is defined as the amount of water existing between FC and PWP. Available soil moisture holding capacity varies widely with differing soil types, depending on the soil's physical and chemical properties.

The available soil moisture holding capacity not only differs among soils but may be further influenced by varying atmospheric conditions or seasons, even for the same soil. Both the FC and PWP are usually determined by laboratory methods, although both are best estimated by "in-situ" methods. FC, PWP, and potentially available soil moisture values for 34 Ohio soils are given in Table 1 for both 30- and 42-inch soil profiles.

DIFFERING WATER USE BY MEADOW, WHEAT, AND CORN

The author has observed that each crop has its own distinctive pattern of soil moisture extraction, although total seasonal demand does not differ widely. Meadows, pastures, and fall-sown wheat transpire large amounts of water in April, May, and June.

The loss of soil moisture from cornfields during May and June occurs mainly by surface evaporation, since there is very little transpiration. As corn begins its period of rapid growth and transpiration increases, the bulk of moisture extraction takes place directly beneath the rows. With continued growth and extension of the root system, water use increases. During July and August, corn transpires more water than meadow since this is the period of rapid vegetative growth and leaf area is approaching its maximum. When the reproductive stage is reached, leaf growth subsides and transpiration declines rapidly, ceasing at maturity.

There is usually a late season decrease in total water use by all crops, starting in early September. The transpiration rate declines as the evaporative demand decreases because of lower air temperatures and shorter days. Soil moisture is usually at its lowest during this period.

The amount of water transpired by a crop is influenced in part by the volume of soil occupied by the rooting system. As long as there is a plentiful water supply in the topsoil, the bulk of water removed as ET will be from this horizon. As the topsoil is depleted of its available moisture supply, the subsoil provides an increasing portion of needed moisture. Since rooting depth varies among crops, the depth from which moisture is extracted depends on the plant species and its stage of growth. It has been noted that in Ohio, 42 inches can be considered the effective rooting depth for meadow crops and wheat, even though their roots may actually penetrate to 5 feet or more. The zone of significant moisture extraction by corn begins within the top foot and gradually increases to an effective depth of 30 inches by the middle of July.

ET is also affected by stand density and the general vitality of the crop. Dreibelbis (5) found that ET under "improved" cultural practices is significantly greater than that under "prevailing" practices, being primarily due to greater leaf area, deeper root penetration, and increased proliferation resulting from improved practices. Soil fertility may not be directly related to the transpiration rate, although a high level of soil fertility does increase the amount of water transpired.

CROP MOISTURE DEFICIT

Crop moisture deficit (CMD), a useful method of expressing the moisture status of the soil, is defined as the amount of water in inches below soil field capacity. It is computed by adding the difference between ET and precipitation to (or subtracting it from) a previous value.

It would be desirable to use one CMD value for all Ohio soils. To determine whether this is feasible, computed CMD values have been compared with actual soil moisture measurements at several locations.

Available soil moisture capacities for a 42-inch profile range from less than 5.00 inches to more than 9.00 inches (Table 1). In spite of this variability, agreement between computed and actual soil moisture among these soils was surprisingly good. Therefore, it has been concluded that use of a constant available soil moisture capacity for all Ohio soils is justifiable. This simplifies the determination of CMD and avoids the necessity for using an actual value for each soil type.

Soil moisture holding capacity at various depth intervals used in the formula method are as follows:

Depth Interval	(CMD maximum) Available Capacity
Inches	Inches
0-3	0 60
3-6	0 60
6-12	1 20
0-12	2 40
0-24	5 00
0-30	6 00
0-42	8 00

The maximum CMD value for a 42-inch profile has been set at 8.00 inches. This value is used throughout the season for both the wheat and meadow formulas. Since the moisture extraction zone under corn increases gradually to an effective depth of 30 inches from planting to the middle of July, CMD maxima are progressively increased to an upper limit of 6.00 inches. It is assumed that all available soil moisture is exhausted as soon as the computed CMD maximum is reached. However, this is not strictly true for all soil types.

GENERALIZED FORMULA FOR CALCULATING ET

The generalized formula is designed to calculate water loss from the soil as ET. First an initial PE value is determined from an empirical relationship based on mean air temperature. PE represents the maximum ET rate attainable under the most favorable conditions. Hence it is necessary during most of the season to revise it downward. These revisions are accomplished through a system of correction factors representing length of day, degree of soil dryness, stage of crop growth, and character of weather as indicated by the occurrence or non-occurrence of precipitation.

The estimating formula may be expressed as follows:

$$ET = PE \times L \times D \times C \times R$$

where:

ET = Evapotranspiration in inches per day

PE = Potential evapotranspiration in inches per day

L = Correction for length of day

D = Correction for soil dryness

C = Correction for crop stage

R = Correction for occurrence of rain

ET represents total moisture loss to the atmosphere in vapor form and is the "outgo" figure used in the budgeting procedure to determine changes in soil moisture.

PE is the maximum possible ET (before adjusting for day length) and is determined from daily mean air temperature. The empirical relation between PE and mean temperature is given in Table I of the Appendix.

L is the length of day correction. Corrections are smallest at the equinoxes, increasing to a maximum of 1.26 at the summer solstice. Daily corrections are given in Table II of the Appendix.

D is the correction for degree of soil dryness. When soil moisture is at or near field capacity, ET proceeds at the PE rate if other conditions are optimum. As soil moisture is depleted, ET decreases. When the wilting point is reached and CMD has attained its maximum value, D becomes constant, limiting ET to about 40 percent of PE. Soil dryness expressed in terms of a crop moisture deficit (CMD) is used as the argument for determining the dryness correction. The corrections applicable to wheat and meadow are given in Table III of the Appendix.

C is a pooled crop stage correction factor. It takes into account advancing plant development, percent of ground surface covered by vegetation, physiological condition at successive stages, and major cultural operations performed. Characteristic differences among the various crops are expressed principally in the crop stage correction factors given in Tables V, VI and VII of the Appendix.

R is an empirical correction. It is designed to compensate for the expected influence of sunshine and humidity which are not specifically included in the formula. R values are given in Table VIII of the Appendix.

METHOD OF CALCULATION

Since several multiplications are required to obtain an ET estimate, a rapid calculation system is highly desirable. Either a standard slide rule or desk calculator may be used satisfactorily. Since frequent reference to tables is burdensome, a special slide rule has been developed which can be used to select the correction factor and perform the multiplications, all in one operation. Logarithmic scales required for construction of this special slide rule are provided in the back of this bulletin. Instructions for assembling the slide rule are given in the Appendix. The formula has also been programmed for the IBM 1620 computer.

The following is a sample computation for determining ET, using tables in the Appendix.

Given: Crop: Meadow
Date: June 27 (20th day after first cutting)
Mean temp.: 66° F.
Rainfall: 1.42 inches (first day with measurable rain)
CMD June 26: 4.50 inches

From the tables in the Appendix:

PE = 0.184" (Table I)
L = 1.25 (Table II)
D = 0.90 (Table III)
C = 0.77 (Table VII)
R = 0.60" (Table VIII)

Therefore: ET = 0.184" x 1.25 x 0.90 x 0.77 x 0.60 = 0.096" (rounded to 0.10"). The calculated ET of 0.10 inches is the moisture outgo. As given in Table IX of the Appendix, only 90 percent of the 1.42 inch rainfall is credited as income. On June 26, CMD was 4.50 inches. Therefore the new CMD value for June 27 is:

CMD (June 27) = 4.50" + 0.10" —1.28" = 3.32"

ESTIMATING ET AND CMD FOR SPECIFIC CROPS

I. Meadow Formula

The date for starting meadow ET computations is April 1. It is assumed that: (a) the meadow crop has a fully established root system, (b) transpiration will start as soon as air temperatures have risen sufficiently to initiate growth, and (c) soil moisture is equal to field capacity. Experience has shown that a first-year meadow will not transpire at the same rate as a second- or third-year meadow but differences are not sufficient to warrant special provisions in the formula.

The following directions are for making the computations to determine ET, using the correction factors given in Tables II, III, and VII—IX in the Appendix. These corrections are applied to a value for PE initially selected from Table I on the basis of mean temperature. The same rules apply when the special slide rule is employed.

STEP 1. Table II. Length of Day Correction (L): Apply strictly according to calendar dates.

STEP 2. Table III. Dryness Correction (D): Except as noted in the rules below, the previous day's CMD is used as the sole argument for determining the D correction,

Rule 1. The D correction is applied every day except when the previous day's precipitation exceeds this day's computed ET.

Rule 2. The D correction is not applied on successive days with measurable precipitation until the CMD value becomes greater than that on the day before the rainy spell began.

Rule 3. Days with precipitation insufficient to reduce the CMD are treated as dry days; the D correction is applied on the following day.

Rule 4. The D correction is applied on the first day with precipitation, regardless of amount.

Since 42 inches is considered to be the effective rooting zone for meadows, CMD values may range from zero to a maximum of 8.00 inches. ET will equal PE until the CMD has accumulated to 2 inches. CMD may assume negative values (surplus moisture) to a lower limit of —1.00 inches and the D correction remains at 1.00 As the CMD exceeds 2.00 inches, D decreases curvilinearly until the 8.00 inch limit has been reached.

STEP 3. Table VII. Crop Stage Correction (C): Apply in accordance with the following rules.

Rule 1. Corrections are selected according to calendar date from April 1 to the date of first cutting.

Rule 2. If dates of cutting are not known, harvest dates are assumed to be June 15 and August 3.

Rule 3. After each harvest, the C correction is based on the number of days since harvest.

Rule 4. In the event of a third harvest, the schedule of corrections for "third growth" is repeated.

Rule 5. After September 10, C corrections are selected according to calendar dates.

The crop stage correction increases gradually in spring from a starting value of 0.66 until it reaches 1.00 on May 5. With the first cutting, ET is reduced sharply to 40 percent of its former rate due to removal of most of its transpiring foliage. As vegetative regrowth begins, ET increases until after an average of 33 days it again approaches, but does not exceed, 90 percent of PE. There is another sharp reduction with the second harvest, after which ET again recovers, eventually reaching 76 percent of PE. Finally, there is a gradual decline in ET rate at the end of the season, starting in Ohio as early as September 10. This decline cannot be accounted for by soil dryness or prevailing weather conditions.

During the period of most rapid growth, transpiration by meadow is as great as for any other crop and for the entire season it is greater than for most row-planted crops. Since the soil surface is entirely covered with vegetation throughout the season, plants intercept a maximum of solar radiation. Plant height makes comparatively little difference in soil moisture use as long as the soil surface is completely shaded.

STEP 4. Table VIII. Rainy Day Correction (R): Apply according to number of consecutive days with measurable precipitation. To compensate for humidity and cloudiness which are not specifically a part of the formula correction factors, a simple correction based on the occurrence or non-occurrence of precipitation is employed. This is an arbitrary correction of 60 percent for the first day, 50 percent for the second, and 40 percent for the third or more days in succession having measurable precipitation.

STEP 5. Table IX. Allowance for Runoff: Runoff from heavy precipitation is recognized by crediting 90 percent of measured rains between 1 and 2 inches and 75 percent of those exceeding 2 inches.

STEP 6. ET Determination: This is the end result after having applied each of the above corrections to the selected PE value.

STEP 7. Budgeting Procedure: With the computation of ET completed, an estimate of soil moisture for each day is obtained by balancing incoming against outgoing soil moisture through a budgeting system. The following is an example of a balance sheet employed to derive the soil moisture estimate as CMD. Some of the special rules governing the application of various correction factors are illustrated.

The normal starting date for computing ET and CMD for meadow is April 1, at which time the CMD = 0. Assuming CMD accumulated to 3.16 inches by July 15, computations were made according to the following pattern:

1. Since there had been a prior harvest, the number of days since first harvest was used to determine the crop stage correction (C) up to the date of the second cutting (July 22). After July 22, the sequence of day numbers started again with 1. Corrections thereafter were obtained from the sixth column of Table VII.
2. The R correction (Table VIII) was applied on all days with measurable precipitation.
3. The D correction was suspended on July 20 and 28 since each followed the cessation of precipitation. Note that the trace precipitation on July 20 was not considered a measurable amount and the D correction was not suspended on July 21.
4. On July 31, only 90 percent of the 1.22-inch precipitation was credited to soil moisture. Hence CMD for July 31 was computed as 3.29 + .06 —1.10 or 2.25 inches.

II. Wheat Formula

The procedure for estimating ET for wheat and budgeting soil moisture is identical to that for meadow, except that a different crop stage correction (C) is used. The C correction is obtained from Table V. Computations begin on April 1. Al-

SOIL MOISTURE BUDGET FOR MEADOW—COSHOCTON, OHIO, JULY 1960

Day	Days Since Cutting	Mean Air Temperature	Precipitation	ET	CMD (0-42")
July		°F	Inches	Inches	Inches
15	39	65	00	19	3 16
16	40	68	00	.20	3 36
17	41	71	00	21	3 57
18	42	72	65	13	3 05
19	43	72	49	11	2 67
20	44	67	Trace	20	2 87
21	45	67	00	20	3 07
22	46	72	.00	.22	3 29
	Second cutting July 22				
23	1	76	.00	08	3 37
24	2	73	00	09	3 46
25	3	74	00	09	3 55
26	4	75	24	06	3 37
27	5	75	01	06	3 42
28	6	77	00	12	3 54
29	7	75	00	12	3 66
30	8	75	44	07	3 29
31	9	67	1 22	06	2 25

though roots have not yet penetrated to the 42-inch depth on April 1, this depth is used as the effective rooting depth. During the vegetative growth period, the ET rate for wheat is similar to that for meadow. The C correction for wheat covers two main periods—one spanning the life of the wheat crop and the other following harvest.

Period 1: April 1 through July 19, an average wheat harvest date in Ohio. During this period, ET gradually approaches PE, beginning with 80 percent of PE on April 1 and equalling PE by April 20. ET continues to equal PE until heading about June 5. Thereafter ET declines gradually until its lowest point is reached at or a little before harvest.

Period 2: July 20 through September 30. It is assumed that a meadow forage has been sown either the previous fall or early in the spring. Wheat thus serves as a cover crop for the new meadow. Immediately after wheat harvest, ET increases from 34 percent to 44 percent of PE. From this point, ET continues to approach PE. By the end of August, ET equals 88 percent of PE; by mid-September, it starts to decline.

III. Corn Formula

April is usually a month with dependable precipitation and the evaporative loss of soil moisture during April from a field intended for corn is relatively small. For this reason, the computing season for corn begins on May 1. It is assumed there is no soil moisture deficit (CMD = 0) on May 1. A crop stage correction (C) is not applied until June 21 because transpiration does not become a significant factor until the corn plant has grown to about 18 inches in height.

Although the formula for computing ET for corn takes the same general form as that for meadow and wheat, major differences in correction factors and budgeting procedures are necessary.

The distinctive features of the corn formula are outlined below and explain the principal departures from the simpler meadow-wheat formula.

The term "fallow" is applied to the entire period from May 1 to June 20 since most of the soil moisture removed is by evaporation from the soil surface. As the developing corn crop shades the soil surface, transpiration gradually increases while soil surface evaporation decreases. Moisture extraction by the small corn plants comes from substantially the same soil layers as that removed by evaporation.

The dominant factor controlling the evaporation rate during the fallow period is the dryness or moistness of the soil surface. So budgeting during this period is confined to the top foot of soil. A very moist soil surface loses water at a rate approximately equal to PE until a shallow surface layer becomes dry. Drying of the soil surface severely restricts the rate at which soil moisture can be extracted from the soil layers below. For this reason, the soil profile subject to moisture extraction is divided into four layers as shown in the table below.

These four layers enter into the selection of dryness corrections (D) and determine the method of budgeting gains and losses of soil moisture. It is assumed that all additions and removals of subsurface soil moisture must pass through the surface. Soil moisture changes in any particular layer depend on the soil moisture level of the layer immediately above. A set of special rules derived from these assumptions are given below, together with a sample computation which illustrates their application.

Rule 1: No soil moisture is budgeted from any layer until the one immediately above has been dried to its maximum CMD.

Rule 2: Precipitation is used to satisfy deficits in an upper layer before allowing for percolation to a greater depth.

Rule 3: In cases of heavy precipitation, surplus water may be budgeted into each layer except the top 3 inches. This surplus is represented by

Period	Moisture Extracted by	Depth Profile	CMD Limits Lower	CMD Limits Upper
		Inches	Inches	Inches
Fallow				
May 1 - June 20	Evaporation only	0 – 3	0	90
		3 – 6	—.10	60
		6 – 12	— 30	1 20
		12+	— 30	None
Early vegetative				
June 21 - July 25	Evaporation and transpiration	0 – 24	— 60	5 00
Late vegetative				
July 26 - August 31	Evaporation and transpiration	0 – 30	—.75	6 00

negative values of CMD. Since free water is subject to percolation, it is disposed of gradually by adding + .01 inches per day to the CMD for each horizon until all negative values have been eliminated.

Rule 4: The CMD value used for determining the dryness correction (D) is that for the layer immediately below the one which is at its maximum CMD value.

Rule 5: Any deficit which may exist in a lower layer remains unaffected until the layer above either has reached its limit of dryness or its deficit has been removed by precipitation.

Rule 6: Evaporation from the 0 to 3 inch layer may exceed 0.60 inches since evaporation from the soil surface under bright sunshine may lower the moisture level below the wilting point.

These rules apply exclusively to the "fallow" period for corn. They are in addition to the more generalized rules for applying the D correction as given in the meadow formula.

Runoff occurring as a result of heavy precipitation is greater from bare surfaces than surfaces covered by vegetation. Thus a smaller percentage of the precipitation is credited to the soil moisture account for corn than is the case when budgeting for meadow. Similarly, the R correction on the third and succeeding days with precipitation differs from that in the meadow formula. A more accurate method of estimating runoff utilizing an antecedent precipitation index (API) can be used. However, the added complexity of the routine is hardly justified by the small improvement in results.

Application of the above rules is illustrated in the following table, which is a sample budget sheet for corn.

SOIL MOISTURE BUDGET FOR CORN—COSHOCTON, OHIO, MAY 1949

Day	Mean Temperature	Rainfall	ET	Crop Moisture Deficit by Depths 0-3"	3-6"	6-12"	12"+
May	°F	Inches	Inches	Inches			
1	67		.17	.17	0	0	0
2	65		16	.33	0	0	0
3	68		.16	.49	0	0	0
4	74		16	.65	0	0	0
5	76		15	.80	0	0	0
6	75		14	90	.04	0	0
7	58		08	.90	.12	0	0
8	60		08	90	20	0	0
9	62	.03	05	.90	22	0	0
10	50		05	.90	27	0	0
11	50		05	.90	32	0	0
12	55		06	.90	.38	0	0
13	63		08	.90	46	0	0
14	68		09	.90	55	0	0
15	68	.38	05	57	55	0	0
16	66	.06	09	60	55	0	0
17	72		20	.80	55	0	0
18	73	.06	08	82	.55	0	0
19	72	.44	07	.45	.55	0	0
20	56	.14	05	.36	55	0	0
21	56	.31	05	.10	55	0	0
22	66	1.24*	07	0	—.10	—.11	0
23	65	.05	.07	.02	— 09	—.10	0
24	58	.10	.05	0	—.08	—.09	0
25	50		.09	.09	— 07	— 08	0
26	55	.21	.07	0	— 06	—.07	0
27	48	.02	.04	.02	— 05	—.06	0
28	50		.10	.12	— 04	— 05	0
29	58		.14	.26	— 03	— 04	0
30	60		.14	.40	— 02	—.03	0
31	70		.17	.57	— 01	—.02	0

*Assumed 75% infiltration, crediting 93" to moisture account

Fallow Period: May 1 to June 20.

Example 1: May 7 — See Rule 1 (page 7) and Rule 6 (page 8).

Since the 0-3 inch horizon has reached its maximum CMD, the argument for the D correction is .04 inches (May 6) for the 3-6 inch horizon. Interpolating upward from .10 inches in Table IV, the D correction becomes .51 and, when used as the value for D in the formula, gives an ET estimate of .078 or .08 inches. The new CMD for May 7 becomes .04 + .08 or .12 inches in the 3-6 horizon. CMD for the 0-3 inch horizon remains at its maximum value.

Example 2: May 15 — See Rules 2 and 5 (pages 7 and 8).

Precipitation of .38 inches exceeds the computed ET by .33 inches, which reduces the CMD in the top horizon from .90 to .57 inches. So the argument for the D correction on May 16 shifts from the 3-6 inch to the 0-3 inch horizon.

Example 3: May 22 — See Rules 2 and 3 (page 7), Table IV (page 14), and Table IX (page 16).

Precipitation measured 1.24 inches and therefore only 75 percent (.93 inches) should be credited toward a reduction of CMD. After subtracting an ET of .07 inches, the .86 inch remainder is sufficient to cancel the deficits in both the 0-3 and 3-6 inch horizons, with .21 inches surplus.

Vegetative Period: June 21 to August 31.

With a rapid increase in vegetative growth, soil moisture extraction takes place primarily as transpiration. So the bulk of the water removed from the soil mass occurs without having to pass through the soil surface. ET becomes less dependent on surface dryness. During the early portion of the vegetative period (June 21 - July 25) the effective rooting depth is considered to be 24 inches, with a CMD maximum of 5.00 inches. As corn plants approach their full height, the effective profile increases to 30 inches and the CMD maximum to 6.00 inches. Since it is no longer necessary to budget soil moisture from the four layers separately, a summed CMD value for the 24-inch profile is obtained for June 20 by adding together the separate values, as shown below.

Until June 20, the soil surface remains essentially bare and there is no need for a crop stage correction (C). However, a C correction is introduced June 21 to take into account increasing transpiration. Its numerical value starts at .50 but increases rapidly until the maximum value of 1.00 is reached on July 25. This maximum is maintained until August 20. For the remainder of August, the numerical value declines from 1.00 to .57 by August 31.

Except for the specified limits on CMD accumulations, the method of applying all corrections remains the same throughout the vegetative period. The formula assumes its complete form on June 21 and the budgeting procedure used is essentially the same as for meadow and wheat. D corrections are taken from Table IV, C corrections from Table VI, and R corrections from the second column of Table VIII. The adjustment for large precipitation amounts differs from that for meadow, as can be seen in Table IX, since runoff from bare ground exceeds that from a surface completely covered with vegetation.

Regardless of the method used for calculating ET, it is still necessary to keep in mind the special rules for applying C and D corrections given on pages 5, 7, and 8. Budgeting of soil moisture into and out of the soil profile is accomplished with the aid of budget sheets such as that shown on page 8.

LITERATURE CITED

1. Arkley, R. J. and R. Ulrich. 1962. The use of calculated, actual and potential evapotranspiration for estimating potential plant growth. Hilgardia 32: 443-462.
2. Barger, G. L., R. H. Shaw, and R. F. Dale. 1959. Chances of receiving selected amounts of precipitation in the north central region of the U. S. NC-26 report pub. by Agr. and Home Econ. Exp. Sta., Iowa State Univ., Ames.
3. Blaney, H. F. and W. D. Criddle. 1950. Determining water requirements in irrigation areas from climatological and irrigation data. USDA, Soil Conservation Service, SCS-TP-96.

SOIL MOISTURE BUDGET FOR CORN—COSHOCTON, OHIO, JUNE 1949

Day	Mean Temperature	Precipitation	ET	Crop Moisture Deficit by Depths 0-3"	3-6"	6-12"	12"+
June	°F	Inches	Inches		Inches		
19	78	0	.09	.90	.60	.46	0
20	80	0	.08	.90	.50	.54	0
					0-24-inch profile		
20	Consolidated CMD for 0-24 inches				2.04		
21	78	.02	.07		2.11		
22	72	0	.08		2 19		
23	72	0	.14		2.33		

4. Decker, W. L. 1964. Total energy budget of the plant canopy and its relationship to evapotranspiration from corn. Mo. Agr. Exp. Sta., Res. Bull. 854.
5. Dreibelbis, F. R. 1963. Land use and soil type effects on the soil moisture regimen in lysimeters and small watersheds. Proc., Soil Sci. Soc. of Amer. 27: 455-460.
6. Jensen, M. E. and H. R. Haise. 1963. Estimating evapotranspiration from solar radiation. J. of Irrigation and Drainage Div., ASCE, 89: 15-41.
7. Penman, H. L. 1948. Natural evaporation from open water, bare soil and grass. Proc. Roy. Soc. A. 193: 120-146.
8. Pierce, L. T. 1958. Estimating seasonal and short term fluctuations in evapotranspiration from meadow crop. Bull., Amer. Met. Soc. 39(2):73-78.
9. Shaw, M. D. and W. C. Arble. 1959. Bibliography on methods for determining soil moisture. Penn. State Univ., Eng. Res. Bull. B-78.
10. Tanner, C. B. 1960. Energy balance approach to evapotranspiration from crops. Proc., Soil Sci. Soc. of Amer. 24(1):1-9.
11. Tanner, C. B. and W. L. Pelton. 1960. Potential evapotranspiration estimates by the approximate energy balance method of Penman. J. Geophys. Res. 65:3391-3413.
12. Thornthwaite, C. W. 1948. A rational approach toward classification of climate. Geophys. Rev. 38: 55-94.
13. Van Bavel, C. H. M. 1959. Agricultural drought and water surplus in the lower Mississippi valley. USDA, Tech. Bull. 1209.

TABLE 2.—Method for Selecting Proper Movable Slide for the Slide Rule Computation of ET, Using the Meadow, Wheat, and Corn Formulas.

Meadow Formula

Period	Movable Slides to be Used: Upper	Movable Slides to be Used: Lower	C_1 scale graduated by
April 1 to first harvest	L_1 D	C_1 R	Calendar dates. Use May 5 graduation until first harvest.
First harvest to second harvest	L_1 or L_2 D or D	C_2 R	Number of days since first harvest. If cutting date not known, use June 15 or some preferred date.
Second harvest to Sept. 10 (repeat if third harvest made)	L_2 D	C_3 R	Number of days since second harvest. If cutting date not known, use August 3 or some preferred date.
Sept. 11 to end of season	L_2 D	C_4 R	Calendar dates.

Wheat Formula

Period	Upper*	Lower	Explanation
April 1 thru June 5	L_1 D	Wheat C_1 R	Set C_1 at 100% from April 20 thru June 5.
June 6 thru July 20	L_1 or L_2 D or D	Wheat C_2 R	Change upper movable slide from L_1/D to L_2/D June 21.
July 21 thru Sept. 5	L_2 D	Wheat C_3 R	
Sept. 6-30	L_2 D	Wheat C_4 R	

*Both L/D slides are the same ones used for the meadow formula.

Corn Formula

Period	Upper	Lower	Explanation
Fallow period May 1 - June 20	L D_1	Corn C_1 R	Set C_1 scale at 100%.
Early vegetative June 21 - July 25	L D_2	Corn C_1 R	Use calendar dates on C scale.
Late vegetative July 26 - Aug. 31	L D_3	Corn C_2 R	Use calendar dates on C scale.

APPENDIX

SPECIAL SLIDE RULE TO COMPUTE ET

The slide rule can be used for computing ET for meadow, wheat, and corn by using the proper slides for each crop. The rule consists of two fixed scales mounted on the upper and lower edges of a suitable backing board with sufficient space between for two movable slides. The mean temperature scale (T) is mounted along the upper edge and the ET scale along the bottom edge. The two movable slides are used for applying the four correction factors: length of day (L), dryness (D), crop stage (C), and rainy day (R). Printed scales for constructing the slide rule may be found in the back of this bulletin.

Constructing the Slide Rule

The body of the rule consists of a backing board of 5/8- or 3/4-inch hardwood or plywood 4-1/32 inches wide and 20 inches long. The fixed scales, T and ET, are mounted along the upper and lower edges respectively, making sure that their center lines are *exactly opposite each other*. The movable scales are attached to the face of 1/4-inch tempered hardboard strips, each 1 inch wide and 20 inches long.

The upper movable slide L/D selects the appropriate PE value from the temperature scale (T), then corrects it for length of day (L) and soil dryness (D). The lower movable slide C/R applies the crop stage (C) and rainy day (R) corrections. The corrected ET in inches per day appears on the lower scale.

Operating the Slide Rule

Slide rule computations follow the same pattern, regardless of which crop is under consideration: meadow, wheat, or corn. However, care must be taken to insert the correct pair of movable slides. Table 2 gives the slides to be paired for making the computations within each growth period for all three crops: meadow, wheat, and corn. The following steps are taken in the order given:

Step 1: Take the upper movable slide and set the proper date on the L scale opposite the day's mean temperature on the T scale.

Step 2: Take the lower movable slide and set the C scale either by date or number of days since harvest opposite the previous day's CMD on the D scale.

Step 3: Read ET from the bottom scale opposite the R scale graduation indicating the occurrence or non-occurrence of precipitation.

Step 4: Compute a new CMD value for the current day.

The 4-step procedure for computing meadow ET with the slide rule is illustrated in the following examples taken from the budget sheet on page 6.

Example 1—Date: July 16. Insert slides L_2/D and C_2/R.

Step 1: Set July 16 on L_2 scale opposite 68° on the T scale.

Step 2: Set 35+ on C_2 scale (40th day) opposite 3.16 on the D scale.

Step 3: Read .17 from ET scale opposite none on R scale since no precipitation occurred.

Step 4: CMD for July 16 becomes 3.16 + .17 or 3.33 inches.

Example 2—Date: July 19. Insert slides L_2/D and C_2/R.

Step 1. Set July 19 on L_2 scale opposite 72° on the T scale.

Step 2: Set 35+ on C_2 scale (43rd day) opposite 2.0 in. or less on D scale. (D correction is suspended on a day following precipitation which exceeds ET. See Rule 2, page 5.)

Step 3: Read .11 from ET scale opposite 2nd on R scale.

Step 4: CMD for July 19 becomes 3.05 + .11 —.49 or 2.67 inches.

Example 3—Date: July 23, second harvest completed. Insert slides L_2/D and C_3/R.

Step 1: Set July 23 on L_2 scale opposite 76° on the T scale.

Step 2: Set 1 on C_3 scale (first day after 2nd cutting) opposite 3.29 on D scale.

Step 3: Read .08 from ET scale opposite none on R scale.

Step 4: CMD for July 23 becomes 3.29 + .08 or 3.37 inches.

For additional examples of the budgeting procedure, see page 9. Although the corn formula is more complex, the same 4-step procedure for computing ET is used. Examples on page 9 refer to the budget sheet on page 8 and demonstrate the method of budgeting incoming and outgoing soil moisture for the four separate horizons during the fallow period in the corn formula.

APPENDIX TABLES

TABLE I.—Potential Evapotranspiration (PE) for Meadow, Wheat, and Corn Formulas.

Mean Air Temperature °F	PE inches/day	Mean Air Temperature °F	PE inches/day	Mean Air Temperature °F	PE inches/day
31	.016	51	.105	71	.206
32	.020	52	.110	72	.210
33	.024	53	.115	73	.214
34	.028	54	.120	74	.218
35	.032	55	.126	75	.221
36	.036	56	.131	76	.224
37	.040	57	.136	77	.228
38	.043	58	.142	78	.231
39	.046	59	.148	79	.234
40	.051	60	.154	80	.237
41	.056	61	.160	81	.239
42	.061	62	.165	82	.242
43	.066	63	.171	83	.244
44	.070	64	.174	84	.246
45	.074	65	.179	85	.248
46	.079	66	.184	86	.250
47	.086	67	.188		
48	.090	68	.193		
49	.094	69	.197		
50	.099	70	.202		

Note: PE - temperature values shown here apply to climatic conditions such as those found in Ohio but may need to be re-evaluated for other climatic zones.

TABLE II.—Length of Day Correction (L) at 40° Latitude for Meadow, Wheat, and Corn Formulas.

Day	Month: April	May	June	July	August	Sept.
1	1.06	1.16	1.24	1.25	1.18	1.08
2	1.06	1.16	1.24	1.25	1.17	1.08
3	1.07	1.17	1.24	1.25	1.17	1.08
4	1.07	1.17	1.24	1.25	1.17	1.07
5	1.07	1.17	1.24	1.25	1.16	1.07
6	1.07	1.18	1.25	1.24	1.16	1.07
7	1.08	1.18	1.25	1.24	1.16	1.07
8	1.08	1.18	1.25	1.24	1.15	1.06
9	1.09	1.18	1.25	1.24	1.15	1.06
10	1.09	1.19	1.25	1.24	1.15	1.06
11	1.10	1.19	1.25	1.24	1.15	1.05
12	1.10	1.19	1.25	1.23	1.14	1.05
13	1.11	1.20	1.25	1.23	1.14	1.05
14	1.11	1.20	1.25	1.23	1.14	1.04
15	1.11	1.20	1.25	1.23	1.14	1.04
16	1.12	1.20	1.26	1.23	1.13	1.04
17	1.12	1.21	1.26	1.22	1.13	1.03
18	1.12	1.21	1.26	1.22	1.13	1.03
19	1.13	1.21	1.26	1.22	1.12	1.03
20	1.13	1.21	1.26	1.22	1.12	1.03
21	1.13	1.22	1.26	1.21	1.12	1.02
22	1.13	1.22	1.26	1.21	1.11	1.02
23	1.14	1.22	1.26	1.21	1.11	1.02
24	1.14	1.22	1.26	1.20	1.11	1.02
25	1.14	1.23	1.26	1.20	1.10	1.01
26	1.15	1.23	1.26	1.20	1.10	1.01
27	1.15	1.23	1.25	1.19	1.10	1.01
28	1.15	1.23	1.25	1.19	1.09	1.00
29	1.16	1.23	1.25	1.19	1.09	1.00
30	1.16	1.24	1.25	1.18	1.09	1.00
31		1.24		1.18	1.08	

TABLE III.—Soil Dryness Correction (D) for Meadow and Wheat Formulas.

CMD Inches	D Correction	CMD Inches	D Correction	CMD Inches	D Correction
<2.10	1.00				
2.10	1.00	4.10	.92	6.10	.76
2.20	.99	4.20	.92	6.20	.75
2.30	.99	4.30	.91	6.30	.74
2.40	.99	4.40	.91	6.40	.72
2.50	.98	4.50	.90	6.50	.71
2.60	.98	4.60	.90	6.60	.70
2.70	.98	4.70	.89	6.70	.69
2.80	.97	4.80	.88	6.80	.68
2.90	.97	4.90	.87	6.90	.66
3.00	.97	5.00	.86	7.00	.64
3.10	.96	5.10	.85	7.10	.62
3.20	.96	5.20	.85	7.20	.60
3.30	.96	5.30	.84	7.30	.58
3.40	.95	5.40	.83	7.40	.56
3.50	.95	5.50	.82	7.50	.54
3.60	.95	5.60	.81	7.60	.52
3.70	.94	5.70	.80	7.70	.50
3.80	.94	5.80	.79	7.80	.48
3.90	.93	5.90	.78	7.90	.45
4.00	.93	6.00	.77	8.00	.42
				>8.00	.42

TABLE IV.—Soil Dryness Correction (D) for Corn Formula.

	Period									
	Fallow		Early Vegetative (0-24")				Late Vegetative (0-30")			
Depth Inches	CMD Inches	D Correction	CMD Inches	D Correction	CMD Inches	D Correction	CMD Inches	D Correction	CMD Inches	D Correction
	<.10	.80	<1.30	1.00	3.10	.87	<1.60	1.00	3.60	.88
	.20	.78	1.40	.99	3.20	.86	1.70	.99	3.70	.87
	.30	.74	1.50	.99	3.30	.84	1.80	.99	3.80	.86
	.40	.70			3.40	.83	1.90	.99	3.90	.85
0-3	.50	.66			3.50	.81	2.00	.99	4.00	.83
	.60	.62								
	.70	.58								
	.80	.55								
	.90	.52								
	.10	.49	1.60	.99	3.60	.79	2.10	.98	4.10	.82
	.20	.46	1.70	.98	3.70	.78	2.20	.98	4.20	.81
3-6	.30	.44	1.80	.98	3.80	.76	2.30	.98	4.30	.80
	.40	.42	1.90	.97	3.90	.74	2.40	.97	4.40	.78
	.50	.40	2.00	.97	4.00	.72	2.50	.97	4.50	.77
	.60	.38								
	.10	.36	2.10	.96	4.10	.70	2.60	.96	4.60	.75
	.20	.34	2.20	.96	4.20	.68	2.70	.96	4.70	.73
	.30	.33	2.30	.95	4.30	.65	2.80	.95	4.80	.72
	.40	.31	2.40	.94	4.40	.62	2.90	.94	4.90	.70
	.50	.30	2.50	.93	4.50	.59	3.00	.93	5.00	.68
6-12	.60	.29								
	.70	.27								
	.80	.26								
	.90	.25								
	1.00	.24								
	1.10	.23								
	1.20	.23								
	.10	.22	2.60	.92	4.60	.57	3.10	.92	5.10	.66
	.20	.22	2.70	.91	4.70	.54	3.20	.92	5.20	.64
	.30	.21	2.80	.90	4.80	.50	3.30	.91	5.30	.62
12+	.40	.21	2.90	.89	4.90	.46	3.40	.90	5.40	.60
	.50	.21	3.00	.88	5.00	.42	3.50	.89	5.50	.57
	.60	.20								
	.70	.20								
	.80	.20								
									5.60	.54
									5.70	.52
									5.80	.49
									5.90	.45
									6.00	.42

TABLE V.—Crop Stage Correction (C) for Wheat Formula.

	Month					
Day	April	May	June	July	August	Sept.
1	.80	1.00	1.00	.57	.62	.88
2	.82	1.00	1.00	.54	.63	.88
3	.84	1.00	1.00	.52	.64	.88
4	.86	1.00	1.00	.49	.66	.88
5	.88	1.00	.99	.47	.67	.88
6	.90	1.00	.99	.45	.69	.88
7	.91	1.00	.98	.44	.71	.88
8	.93	1.00	.98	.42	.73	.88
9	.94	1.00	.97	.41	.74	.88
10	.95	1.00	.97	.40	.75	.88
11	.95	1.00	.96	.39	.76	.87
12	.96	1.00	.96	.38	.77	.87
13	.96	1.00	.95	.37	.78	.86
14	.97	1.00	.95	.36	.80	.86
15	.98	1.00	.94	.36	.81	.85
16	.98	1.00	.93	.35	.82	.85
17	.99	1.00	.92	.35	.82	.84
18	.99	1.00	.91	.35	.83	.83
19	.99	1.00	.89	.34	.84	.82
20	1.00	1.00	.87	.44	.84	.81
21	1.00	1.00	.86	.46	.85	.80
22	1.00	1.00	.84	.47	.85	.79
23	1.00	1.00	.82	.48	.86	.78
24	1.00	1.00	.79	.50	.86	.77
25	1.00	1.00	.77	.52	.87	.76
26	1.00	1.00	.74	.53	.87	.75
27	1.00	1.00	.70	.55	.87	.74
28	1.00	1.00	.67	.56	.88	.73
29	1.00	1.00	.63	.58	.88	.72
30	1.00	1.00	.60	.60	.88	.70
31		1.00		.61	.88	

TABLE VI.—Crop Stage Correction (C) for Corn Formula.

	Month			Day	June	July	August
Day	June	July	August		Month		
1	N.C.A. June 1-20*	.80	1.00	17		.97	1.00
2		.82	1.00	18		.98	1.00
3		.84	1.00	19		.98	1.00
4		.85	1.00	20		.98	1.00
5		.86	1.00	21	.50	.99	.99
6		.87	1.00	22	.55	.99	.98
7		.89	1.00	23	.60	.99	.96
8		.90	1.00	24	.64	.99	.93
9		.91	1.00	25	.67	1.00	.89
10		.92	1.00	26	.69	1.00	.84
11		.93	1.00	27	.71	1.00	.79
12		.94	1.00	28	.74	1.00	.72
13		.95	1.00	29	.76	1.00	.66
14		.96	1.00	30	.78	1.00	.61
15		.96	1.00	31		1.00	.57
16		.97	1.00	*No correction applied.			

TABLE VII.—Crop Stage Correction (C) for Meadow Formula.

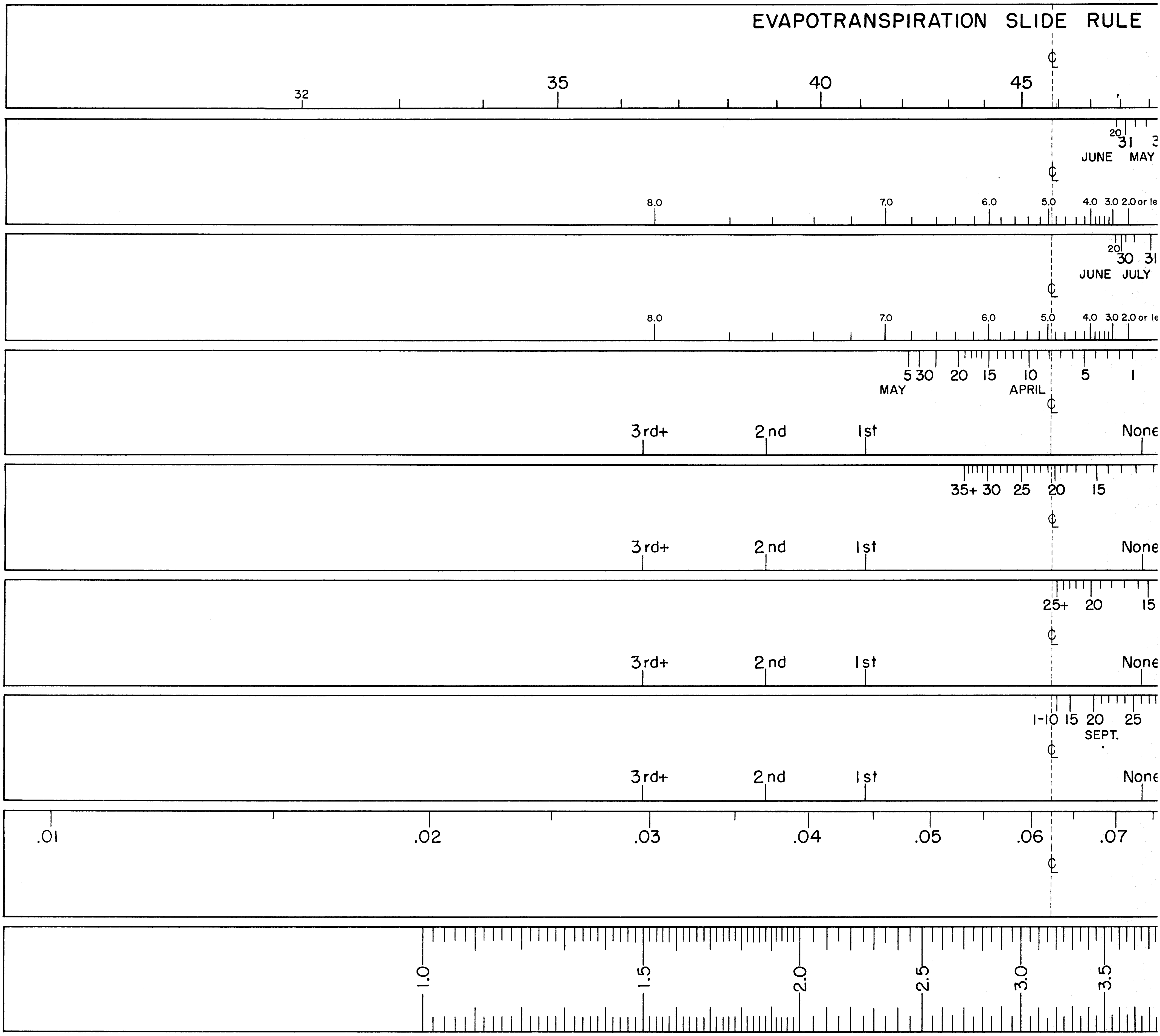
First Growth		Second Growth		Third Growth			
Date	C Correction	No. Days Since 1st Cutting	C Correction	No. Days Since 2nd Cutting	C Correction	Date	C Correction
April						Sept.	
1	.66	1	.41	1	.33		
2	.68	2	.44	2	.36		
3	.70	3	.46	3	.40		
4	.71	4	.48	4	.42		
5	.72	5	.51	5	.44		
6	.74	6	.54	6	.46		
7	.76	7	.56	7	.49		
8	.77	8	.58	8	.51		
9	.78	9	.60	9	.53		
10	.80	10	.62	10	.55		
11	.81	11	.64	11	.57	11	.76
12	.82	12	.65	12	.59	12	.75
13	.83	13	.67	13	.60	13	.75
14	.84	14	.68	14	.62	14	.74
15	.86	15	.70	15	.64	15	.74
16	.87	16	.71	16	.65	16	.73
17	.88	17	.73	17	.66	17	.73
18	.89	18	.75	18	.68	18	.72
19	.90	19	.76	19	.70	19	.72
20	.91	20	.77	20	.71	20	.71
21	.92	21	.79	21	.72	21	.70
22	.93	22	.80	22	.72	22	.69
23	.93	23	.81	23	.73	23	.68
24	.94	24	.82	24	.74	24	.67
25	.95	25	.84	25	.75	25	.66
26	.96	26	.85	26	.75	26	.65
27	.96	27	.86	27	.75	27	.64
28	.97	28	.87	28	.76	28	.64
29	.98	29	.87	29	.76	29	.63
30	.98	30	.88	30 to	.76	30	.62
May		31	.89	3rd cutting		Oct.	
1	.98	32	.89	or Sept. 11		1	.61
2	.99	33	.90	(Repeat in case of		2	.60
3	.99	To 2nd cutting	.90	a third cutting)		3	.59
4	.99					4	.58
5						5	.57
To 1st cutting							
	1.00						

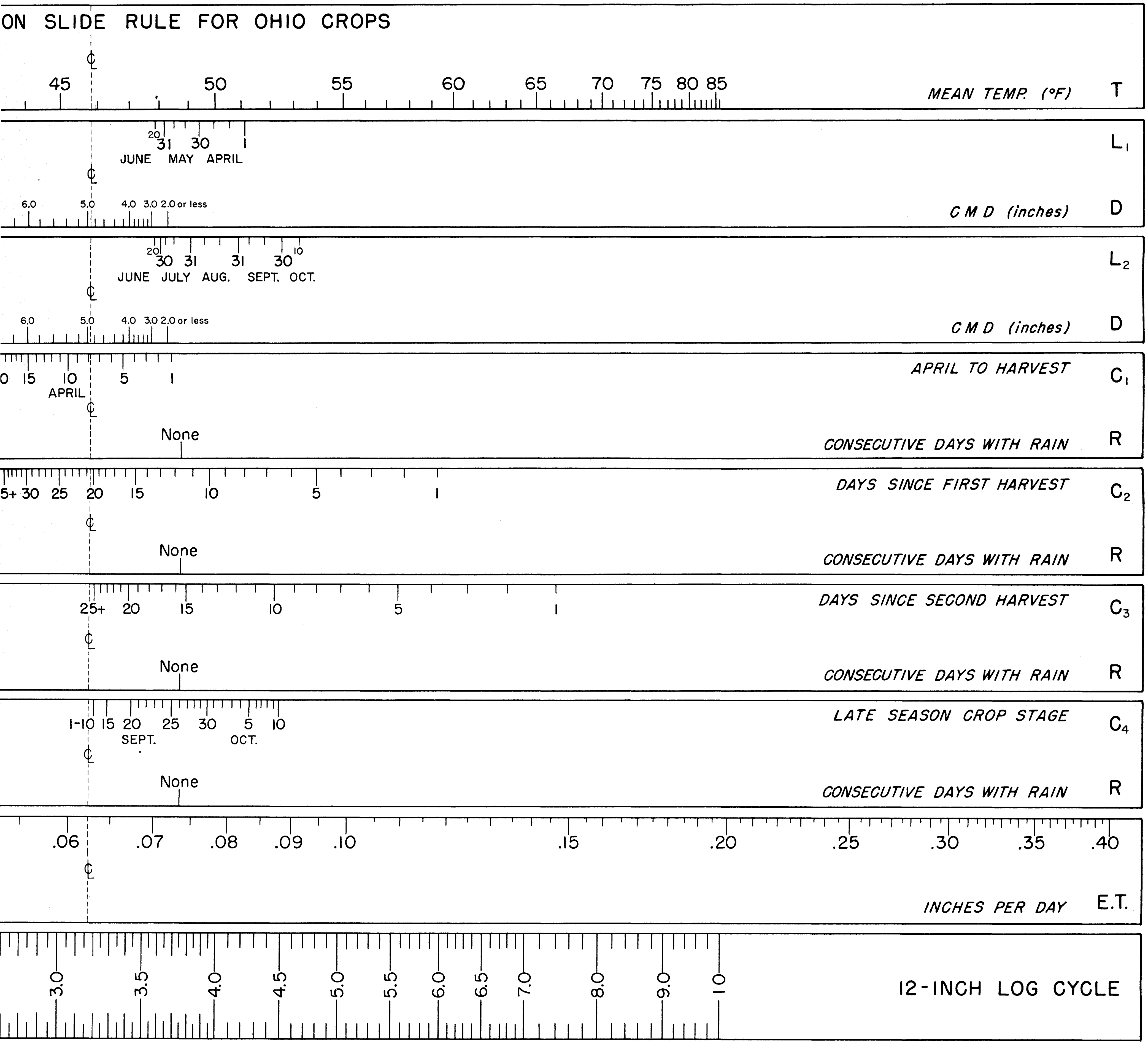
TABLE VIII.—Rainy Day Correction (R) for Meadow, Wheat, and Corn Formulas.

Days with Measurable Precipitation	R Correction: Meadow and Wheat Formulas	R Correction: Corn Formula
No precipitation	1.00	1.00
First day with precipitation	.60	.60
Second day with precipitation	.50	.50
Third and succeeding days with precipitation	.40	.50

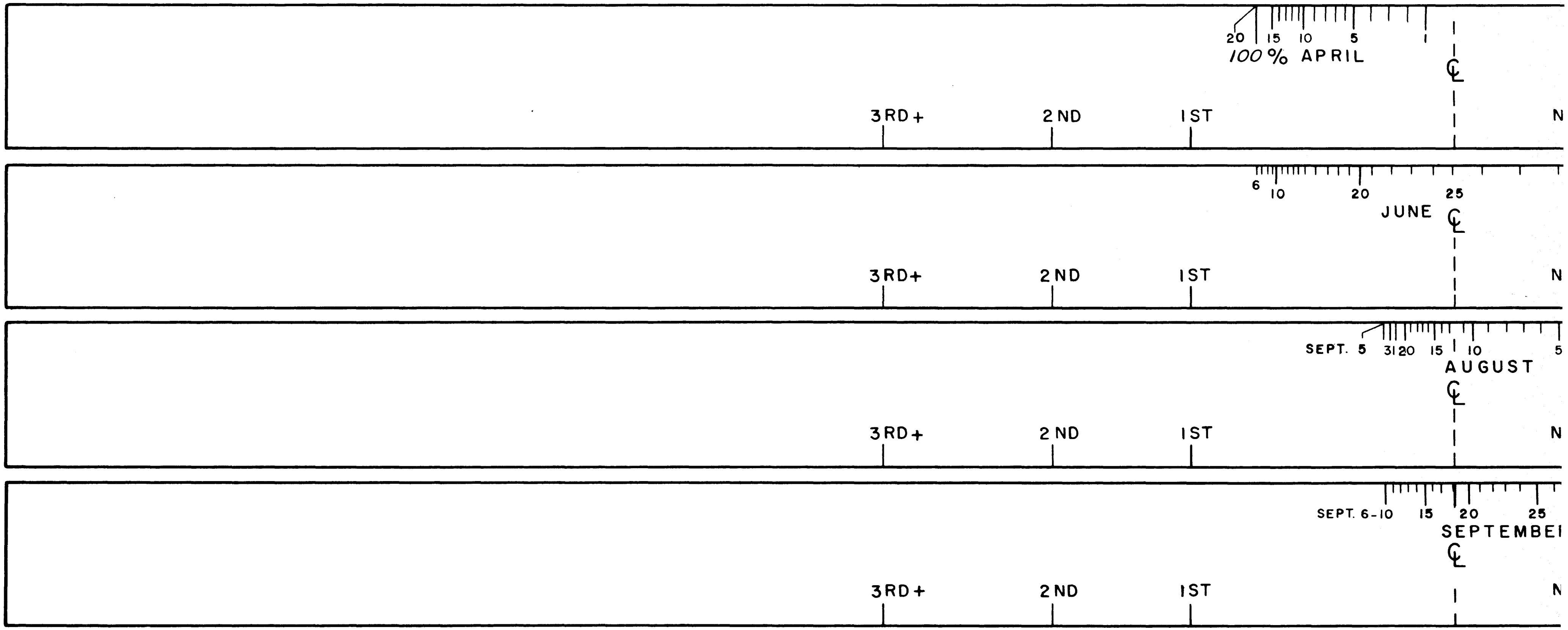
TABLE IX.—Allowance for Runoff for Meadow, Wheat, and Corn Formulas.

Daily Precipitation Inches	Credit to Soil Moisture: Meadow and Wheat Formulas	Credit to Soil Moisture: Corn Formula
0—1.00	100%	100%
1.01—2.00	90%	75%
2.00+	75%	50%

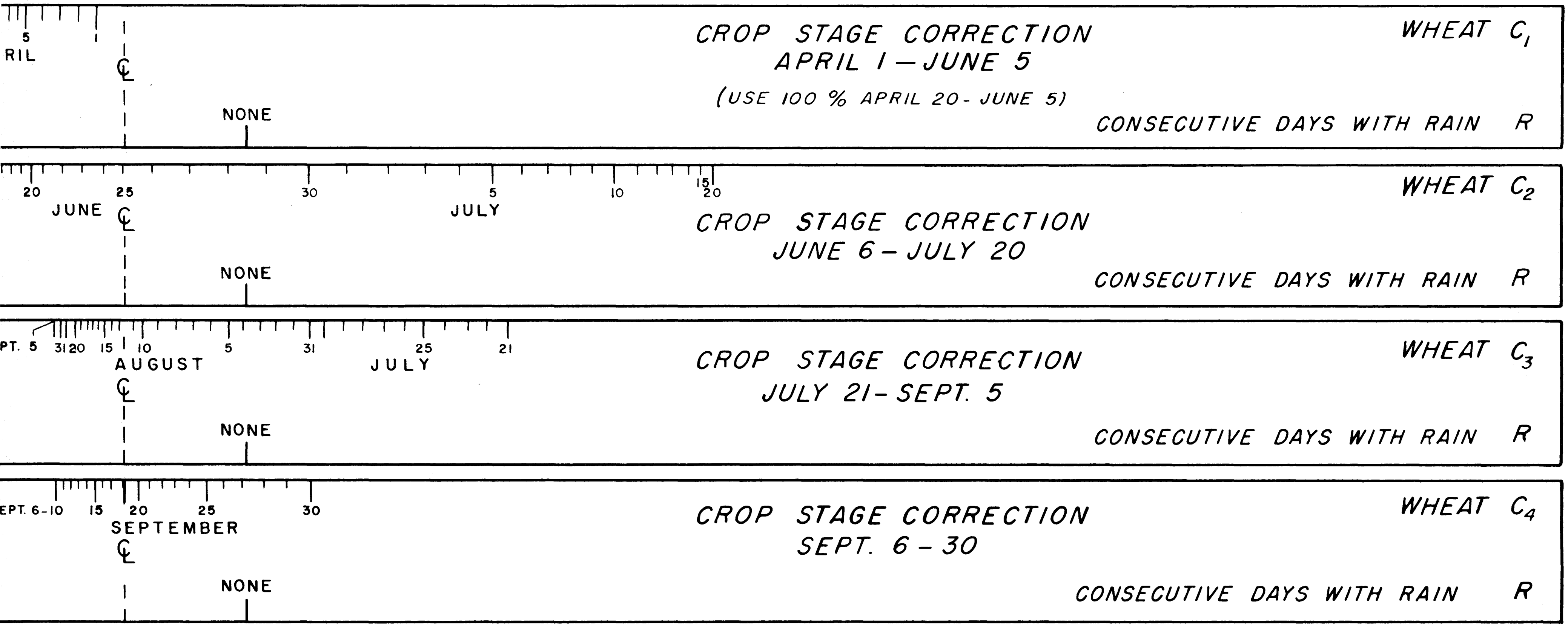

EVAPOTRANSPIRATION SLIDE RULE
32
35
40
45
20 31 3
JUNE MAY
8.0
7.0
6.0
5.0
4.0 3.0 2.0 or le
20 30 31
JUNE JULY
8.0
7.0
6.0
5.0
4.0 3.0 2.0 or le
5 30 20 15 10 5 1
MAY APRIL
3rd+
2nd
1st
None
35+ 30 25 20 15
3rd+
2nd
1st
None
25+ 20 15
3rd+
2nd
1st
None
1-10 15 20 25
SEPT.
3rd+
2nd
1st
None
.01
.02
.03
.04
.05
.06
.07
1.0
1.5
2.0
2.5
3.0
3.5


ON SLIDE RULE FOR OHIO CROPS
45 50 55 60 65 70 75 80 85
MEAN TEMP. (°F)
T
20 31 30 1
JUNE MAY APRIL
L1
6.0 5.0 4.0 3.0 2.0 or less
CMD (inches)
D
20 30 31 31 30 10
JUNE JULY AUG. SEPT. OCT.
L2
6.0 5.0 4.0 3.0 2.0 or less
CMD (inches)
D
0 15 10 5 1
APRIL
APRIL TO HARVEST
C1
None
CONSECUTIVE DAYS WITH RAIN
R
5+ 30 25 20 15 10 5 1
DAYS SINCE FIRST HARVEST
C2
None
CONSECUTIVE DAYS WITH RAIN
R
25+ 20 15 10 5 1
DAYS SINCE SECOND HARVEST
C3
None
CONSECUTIVE DAYS WITH RAIN
R
1-10 15 20 25 30 5 10
SEPT. OCT.
LATE SEASON CROP STAGE
C4
None
CONSECUTIVE DAYS WITH RAIN
R
.06 .07 .08 .09 .10 .15 .20 .25 .30 .35 .40
INCHES PER DAY
E.T.
3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 8.0 9.0 10
12-INCH LOG CYCLE

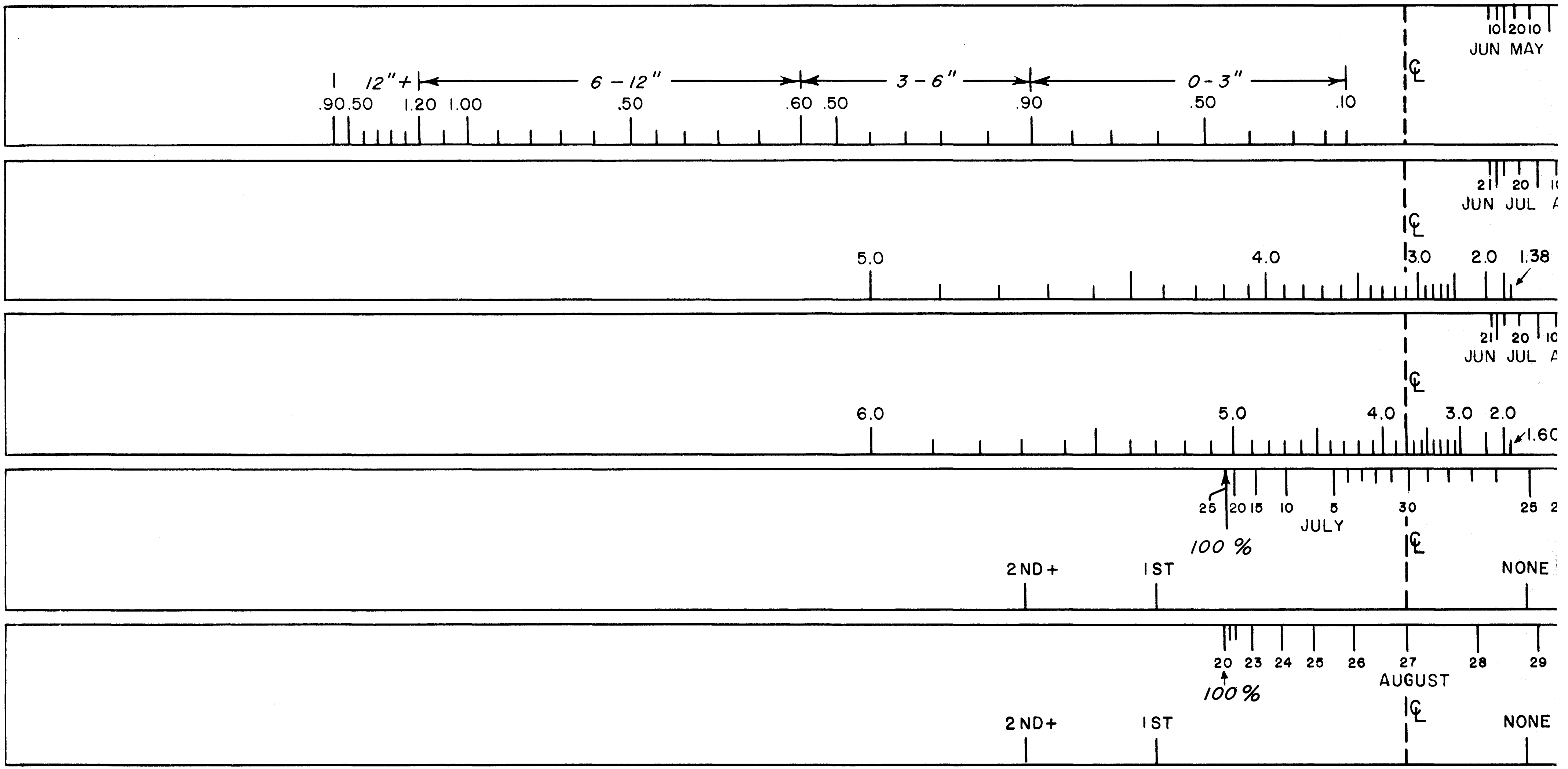
EVAPOTRANSPIRATION SLIDE RULE FOR WHEAT-SUPPLEMENTAL SCALES F



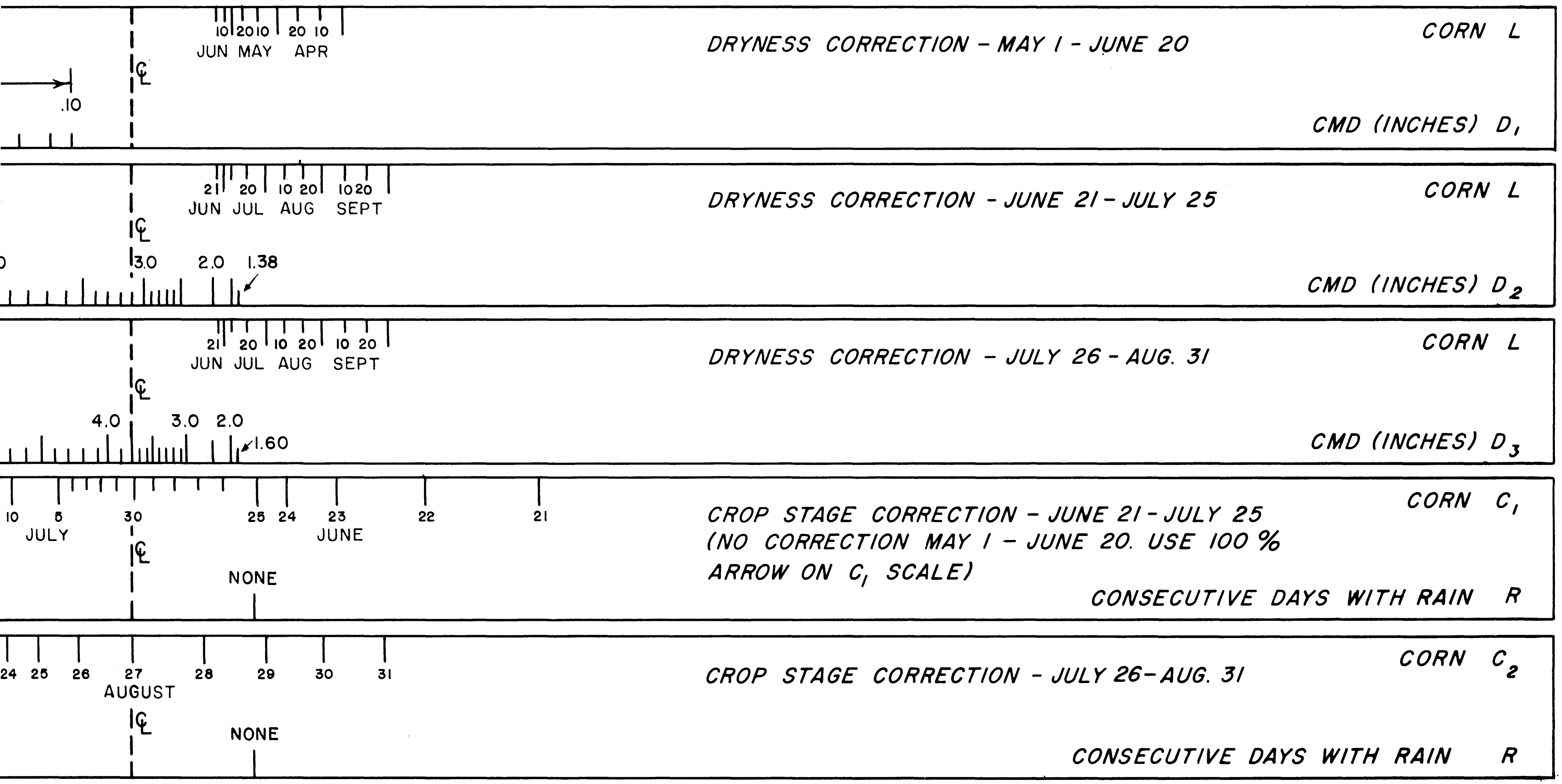
ENTAL SCALES FOR USE WITH MEADOW-ET SLIDE RULE - PIERCE METHOD.



EVAPOTRANSPIRATION SLIDE RULE FOR CORN - SUPPLEMENTAL SCALES FOR



MENTAL SCALES FOR USE WITH MEADOW ET SLIDE RULE - PIERCE METHOD.



The State Is the Campus for Agricultural Research and Development

Ohio's major soil types and climatic conditions are represented at the Research Center's 11 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 14 departments on more than 5900 acres at Center headquarters in Wooster, nine branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 2017 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2039 acres

Mahoning County Experiment Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Central Branch, Vickery, Erie County: 335 acres

Northwestern Branch, Hoytville, Wood County: 247 acres

Southeastern Branch, Carpenter, Meigs County: 330 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Marietta, Washington County: 20 acres

Western Branch, South Charleston, Clark County: 428 acres